A COMPARISON OF THE EFFECTIVENESS OF FORWARD AND BACKWARD CHAINING PROCEDURES WITH RETARDED CHILDREN

An abstract of a Thesis by
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The problem. Very little experimental evidence is available to indicate the conditions under which backward chaining procedures are most effective. This study compared the effectiveness of backward and forward chaining procedures with retarded children on a telephone dialing task.

Procedure. Four retarded children were taught to dial telephone numbers using forward and backward chaining procedures. The number of errors made by subjects as a function of the chaining condition was compared.

Findings. Two subjects performed better under the forward chaining conditions, one subject performed better under the forward chaining condition and another subject did not show a change in performance as a function of the chaining conditions.

Conclusions. The results were inconsistent with previous studies which indicated that forward chaining was more effective than backward chaining for all subjects studied.

Recommendations. Further research should be conducted to investigate the generality of the findings across subjects and tasks.

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TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1

INTRODUCTION

The science of behavior is concerned with prediction and control (Skinner, 1953). Since human behavior is extremely complex, its prediction and control have not been simple tasks. The concept of chaining, however, has enabled psychologists to impose some order on behavior which might otherwise seem incalculable. An analysis of human behavior indicates that many complex actions are composed of discrete responses linked together by stimuli having both discriminative and reinforcing functions. For example, the behavior of making a bed may be conceptualized as twenty individual components, each containing a discriminative stimulus, response and reinforcer (Martin, England, & England, 1971). School related behaviors such as spelling, writing or solving a mathematical problem are actually behavioral chains made up of many smaller sequences of responses (Sulzer & Mayer, 1972).

The concept of chaining was introduced by physiologists to explain the rapid succession of reflexes that followed one another (Exner, 1894, Loeb, 1900; Sherrington, 1906). The essential characteristic of a reflex chain is that each of the successive stimuli elicits a response which becomes a conditioned stimulus for the next response (Kelleher, 1966). The concept was later extended to explain sequences of learned behavior. Such complex behaviors as piano playing,

writing and typing were viewed as compounds of conditioned reflexes. Pavlov (1928) noted, "It is obvious that different kinds of habits based on training, education and discipline of any sort are nothing but a long chain of conditioned reflexes" (p. 237).

It is now evident that the early attempts to explain sequences of learned behavior in terms of conditioned Pavlovian chains were not adequate to enable prediction of complex behavior (Hilgard & Marquis, 1940; Kelleher, 1966). Lashley (1951) indicated that the speed at which a skilled pianist executes a cadenza is so fast that the sensory control by tactile or kinesthetic stimuli is not plausible because neural transmission is too slow.

Skinner's Law of Chaining greatly modified the Pavlovian concept of chaining by including the discriminative and reinforcing functions of stimuli as well as the elicitation function. The distinction between eliciting and discriminative stimuli reflects a major difference between respondent and operant conditioning (Skinner, 1938).

An operant chain is composed of behavioral components, each containing a discriminative stimulus, response, and reinforcer (Reynolds, 1968). Several psychologists have noted that the discriminative stimuli may be either exteroceptive, originating outside of the organism, or proprioceptive, originating from the movements of the organism itself (Keller & Schoenfeld, 1950; Skinner, 1968; Smith & Guthrie,

1921). In either case, the discriminative function of a stimulus is acquired by being associated with a reinforced operant.

The number of responses which make up an operant chain may be few or many. Simple chains involving only a few responses may often be subdivided into many smaller responses. The number of responses in a chain is not infinite, however, because a point will eventually be reached where it will be impossible to discriminate the topographies of two adjacent responses (Millenson, 1967).

The responses in a chain may be classified as either homogeneous or heterogeneous. A homogeneous chain is composed of stimuli and responses which are identical in each successive link (Millenson, 1967). Millenson (1967) also noted that although cases of pure homogeneity are rare, the similarity of the elements (discriminative stimuli as well as responses) in a chain may make mastery of a task difficult for some organisms. Regardless of the similarity of the responses in a behavioral chain, they produce the discriminative and reinforcing stimuli which link the chain together.

Several theorists have discussed the reinforcing function of stimuli in an operant chain (Ferster & Merrott, 1968; Kelleher, 1966; Millenson, 1967; Skinner, 1938, 1968). A procedure which has proven useful in quantitatively assessing the reinforcing power of conditioned reinforcers is

the chained-schedule procedure (Kelleher, 1966; Millenson, 1967). The ability of a conditioned reinforcer to strengthen the response it follows may be proven by breaking the chain at each link. The interruption of the chain at a particular point will extinguish all members of the chain up to the point of interruption (Ferster & Merrott, 1968; Skinner, 1968).

Operant chains with laboratory animals are characteristically established in a backward manner beginning with the last response in the chain (Ferster & Merrott, 1968; Millenson, 1967; Skinner, 1938). As Whaley and Malott (1969) noted, "backward chaining is a standard procedure used for establishing stimulus-response chains in lower animals" (pp. 16-18). There is a theoretical explanation for this approach. In backward chaining the stimulus which is the discriminative stimulus for the terminal response also acts as a conditioned reinforcer for the preceeding response. Since conditioned reinforcers strengthen the responses they follow, responses may be added to the chain in a backward manner (Ferster & Merrott, 1968). In forward chaining the discriminative stimulus for each response also becomes a conditioned reinforcer, however, it preceeds the response to be added. Therefore, new responses are not strengthened by the discriminative stimulus acting as a conditioned reinforcer. Operant chains may also be more difficult to acquire in a forward manner since each new response added to the chain involves the extinction of

previously learned chains (Boren, 1964).

Several authors have indicated that backward chaining may be an effective technique with human subjects as well as laboratory animals. Millenson (1967) suggests that a child should be taught to tie a shoe beginning with the final response (tugging on the bow). McReynolds (1969) taught a child to imitate multi-syllable words by first presenting the final phoneme and then the next to final phoneme until the word was mastered. Backward chaining was also shown to be effective in teaching retarded girls to make beds (Martin, 1971).

In spite of theoretical and practical evidence to support backward chaining as a training tool, casual observation indicates that many chains in everyday life are acquired in a forward chaining manner. Some children may learn to count, spell, read and write beginning with the first response rather than the last. Also, since conditioned reinforcers such as praise and tokens may be used effectively with human subjects, new responses which are added to a chain in a forward manner may also be reinforced. Sulzer (1972) suggests that backward chaining may be used effectively when a child experiences difficulty in acquiring a complex behavior using a forward chaining procedure. Little experimental evidence is available to indicate the conditions under which one procedure may be more effective than the other (Martin, 1971; Sulzer, 1972).

Boren and Devine (1968) devised a method for studying the acquisition of behavioral chains. They trained monkeys to acquire a large number of four response chains consisting of four lever presses. The monkeys were trained on each new chain until a stable number of errors were made. The stable number of errors served as a baseline with which to study the effects of the manipulation of experimental variables. Using a similar design with graduate students as subjects, Kaplan (1972) investigated the efficacy of forward versus backward chaining on a four response lever pressing task. She recorded two response measures under each experimental condition: the number of errors and the length of time required to learn each chain. The results of that study indicated that forward chaining was either equal to or more effective than backward chaining for each of the 22 subjects studied. Kaplan (1972) noted that further investigation was needed to test the generality of her findings across subjects and tasks.

The present study was undertaken to investigate the effectiveness of backward versus forward chaining with retarded children on an applied task. Many retarded children have difficulty in dialing a telephone number even though they may be capable of discriminating the numerals zero to nine. Dialing most telephone numbers involves a seven response chain consisting of either semi-circular finger movements on a dial type telephone or button presses on a touch-tone

telephone. The present study was also intended to develop a method of training retarded children to "dial" a telephone number correctly.

Chapter 2

METHOD

Subjects

Four mildly retarded children (two boys and two girls) served as subjects. The subject's average chronological age was 11.8 yr. (range 10.4 to 13.2) and their respective IQ scores were 65, 70, 73, and 80 on the Stanford Binet Intelligence Scale. All four subjects were residents at a training center for retarded children and had been involved in a token economy program.

Apparatus

A touch-tone desk telephone was supported by a desk at which two chairs were placed. A subject sat in one chair directly in front of the telephone and the experimenter sat in the second chair immediately to left of the subject. Plastic poker chips served as tokens and were placed by the experimenter into a cup on the desk. The cup was placed equidistant from the experimenter and the subject. The study was conducted in a room 12 feet wide and 15 feet long.

Experimental Design

Each subject served as his own control in a repeated measures, A-B-A design. All subjects were required to perform 15 different behavioral chains, each consisting of seven button presses on a touch-tone telephone. Numbers chosen for

each chain were randomly selected except that no number was permitted to appear more than once in each chain. The forward, FC, and backward, BC, chains were acquired in the following manner:

Condition	Experimental Phase		
	A	B	A
1. Ss 1 ans 2	FC FC FC FC FC	BC BC BC BC BC	FC FC FC FC FC
2. Ss 3 and 4	BC BC BC BC BC	FC FC FC FC FC	BC BC BC BC BC

Under condition 1, subjects 1 and 2 performed five forward chains followed by five backward chains and then five forward chains again. Under condition 2, for subjects 3 and 4, the order was reversed (i.e., backward chaining first and forward chaining following). This design was utilized to counterbalance the possible effects of the sequential presentation of the experimental phases.

Reliability checks on the scoring of correct and incorrect button presses were obtained by having an observer independently rate one training session during each experimental phase for each subject. The reliability index was the ratio of agreements/agreements plus disagreements for each response rated. The reliability index for all checks made by the independent observer was 100%.

Procedure

The following standardized directions were read to each subject as soon as the subject was seated at the desk.

> I'm going to let you earn some tokens by pressing buttons on this telephone. When you have pressed the buttons the way I want you to, you may exchange your tokens for 10 cents. Now I'll show you how you may earn the tokens. I'm going to press some buttons and then it will be your turn to press the same buttons.

A seven button press chain was acquired by the subject during each session. Sessions were composed of trials consisting of the presentation of the instruction "your turn" given by the experimenter, followed by the subject's response. Button presses were added to the chain only after the subject had responded correctly during three consecutive trials on previous responses in the chain. The experimenter modeled the button press(es) on the first two trials and presented only a verbal instruction on the third trial.

During the forward chaining procedure the experimenter presented the first and second trials of the session by saying "watch me," modeling the first button press and then saying "your turn." The experimenter allowed 10 seconds for the subject to press the previously modeled button. If the subject responded correctly on the third trial, the experimenter praised the subject and placed a token in the cup in front of the subject. After the subject had responded correctly on three consecutive trials, the experimenter presented the first and second button presses in the same

manner and delivered a token when the third trial was completed correctly. The first, second and third button presses were then presented to the subject. In this way, one number at a time was added to the chain in a forward progression until the subject had mastered the entire button press chain.

During the backward chaining procedure the subject was also required to correctly complete three trials before the presentation of each new button press. The backward chaining procedure, however, began with the last response in the chain. Thus, the seventh button press was presented first, followed by the sixth and seventh presses, followed by the fifth, sixth and seventh button presses. In this way one response at a time was added in a backward progression until the subject had acquired the entire seven response chain.

If the subject made an incorrect response (i.e., pressed the wrong button, pressed buttons not modeled by the experimenter, or pressed buttons in an incorrect order), the experimenter said "no" and turned away from the subject for 10 seconds. After the 10 second time out period, the most recently added button press was removed from the chain and the experimenter modeled the remaining button presses. When the subject performed the remaining button presses correctly on three consecutive trials the experimenter added the next number to the chain. No tokens were delivered during the remedial trials.

The response measure used in this study was the number of incorrect button presses made by a subject in acquiring each chain. These data were graphed cumulatively and compared across chaining procedures.

Chapter 3

RESULTS

The cumulative number of errors made by each subject compared to every other subject is shown in Figure 1. Although subjects were relatively homogeneous in terms of their IQ scores, there was a wide difference in the cumulative number of errors made by each subject as compared to every other subject.

Figure 1 also shows that subject 3, who made more errors than subjects 1, 2 and 4 combined, was the only subject who did not show a change in error rate related to the different experimental phases.

Figures 2, 3, 4 and 5 show the cumulative number of errors made by each subject during each experimental phase. Figure 2 indicates that subject 1 made fewer errors during the backward chaining phase than during forward chaining. Subject 1 maintained a relatively steady state of errors during each experimental phase, although error rates between phases were substantially different.

Figure 3 shows that subject 2 made fewer cumulative errors during the backward chaining phase than during either of the forward chaining phases. However, most of the errors made by subject 2 occurred during the acquisition of chains three and 13. Thus the total number of errors made by subject 2 during the forward chaining phases was inflated by the

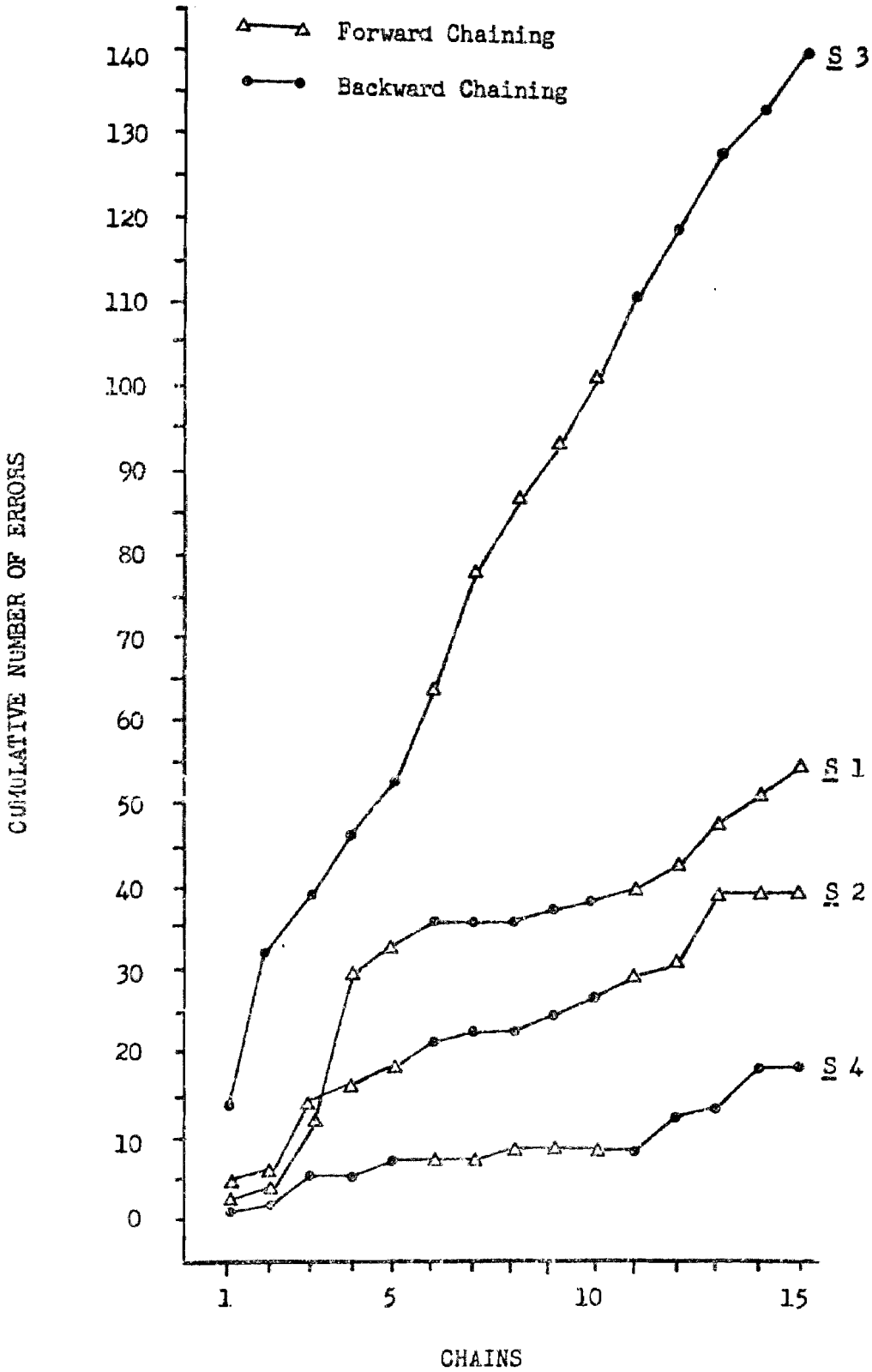

Fig. 1. Cumulative number of errors made by all subjects in acquiring all 15 chains.

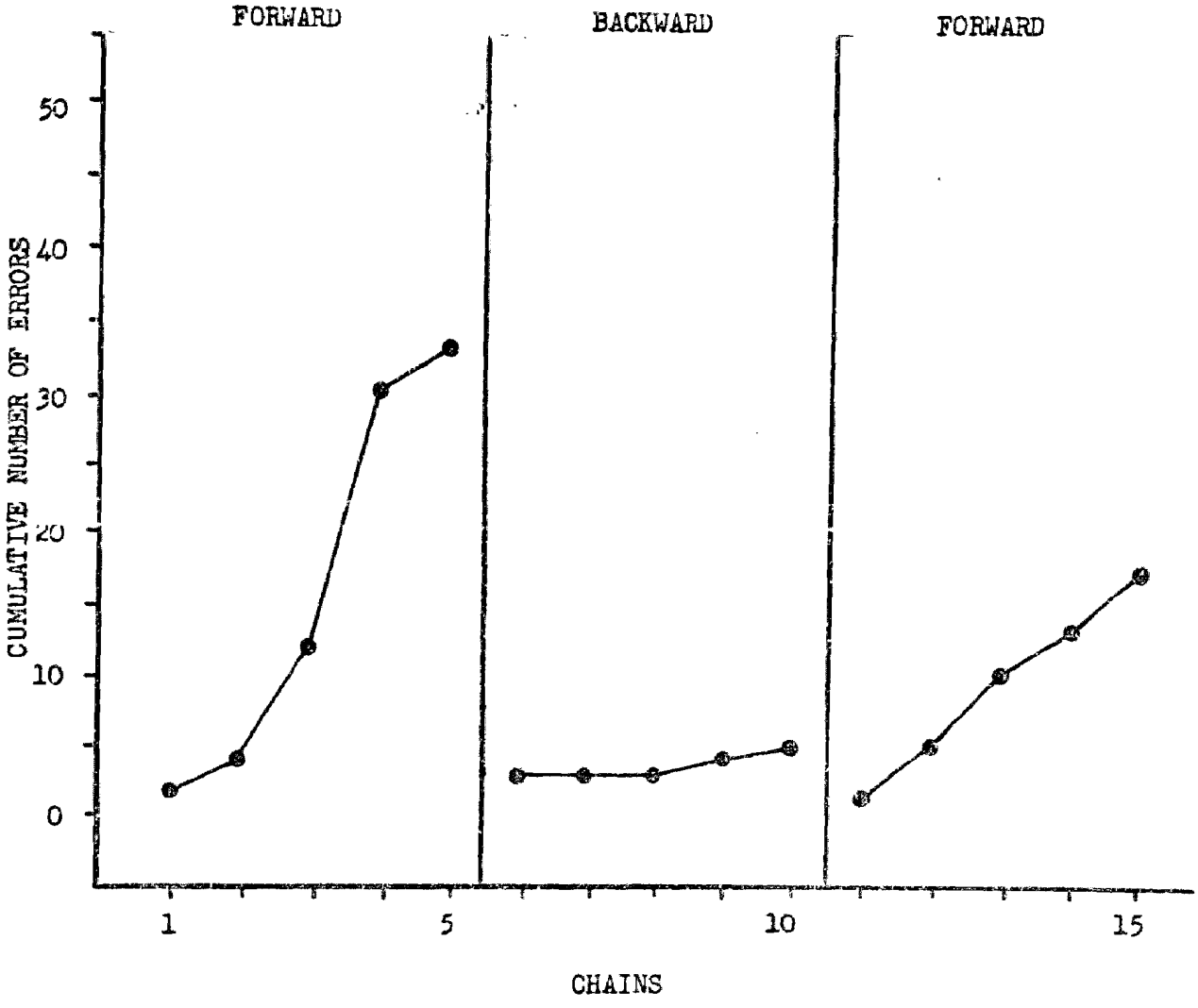

Fig. 2. Cumulative number of errors made by subject 1 during each experimental phase.

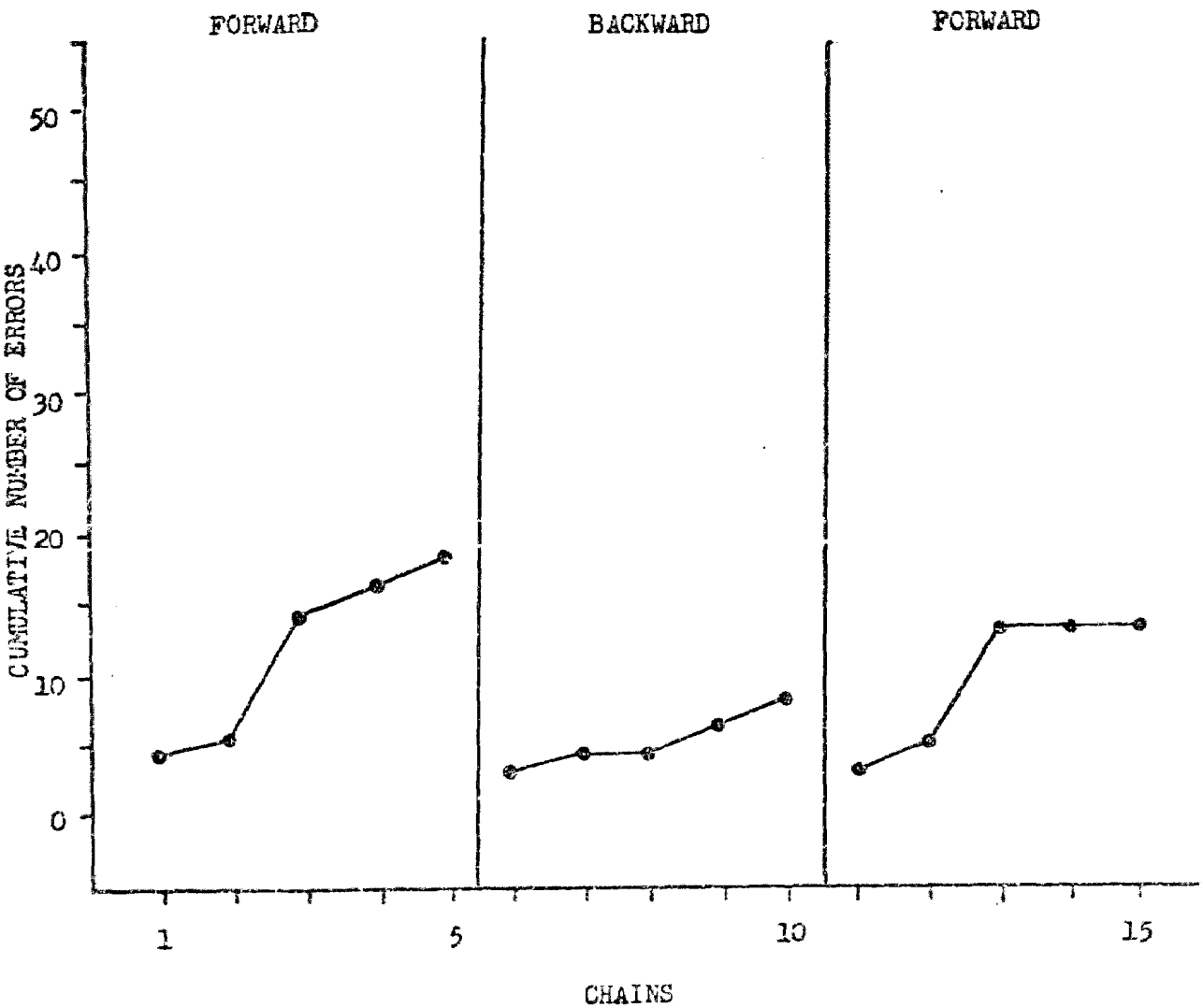

Fig. 3. Cumulative number of errors made by subject 2 during each experimental phase.

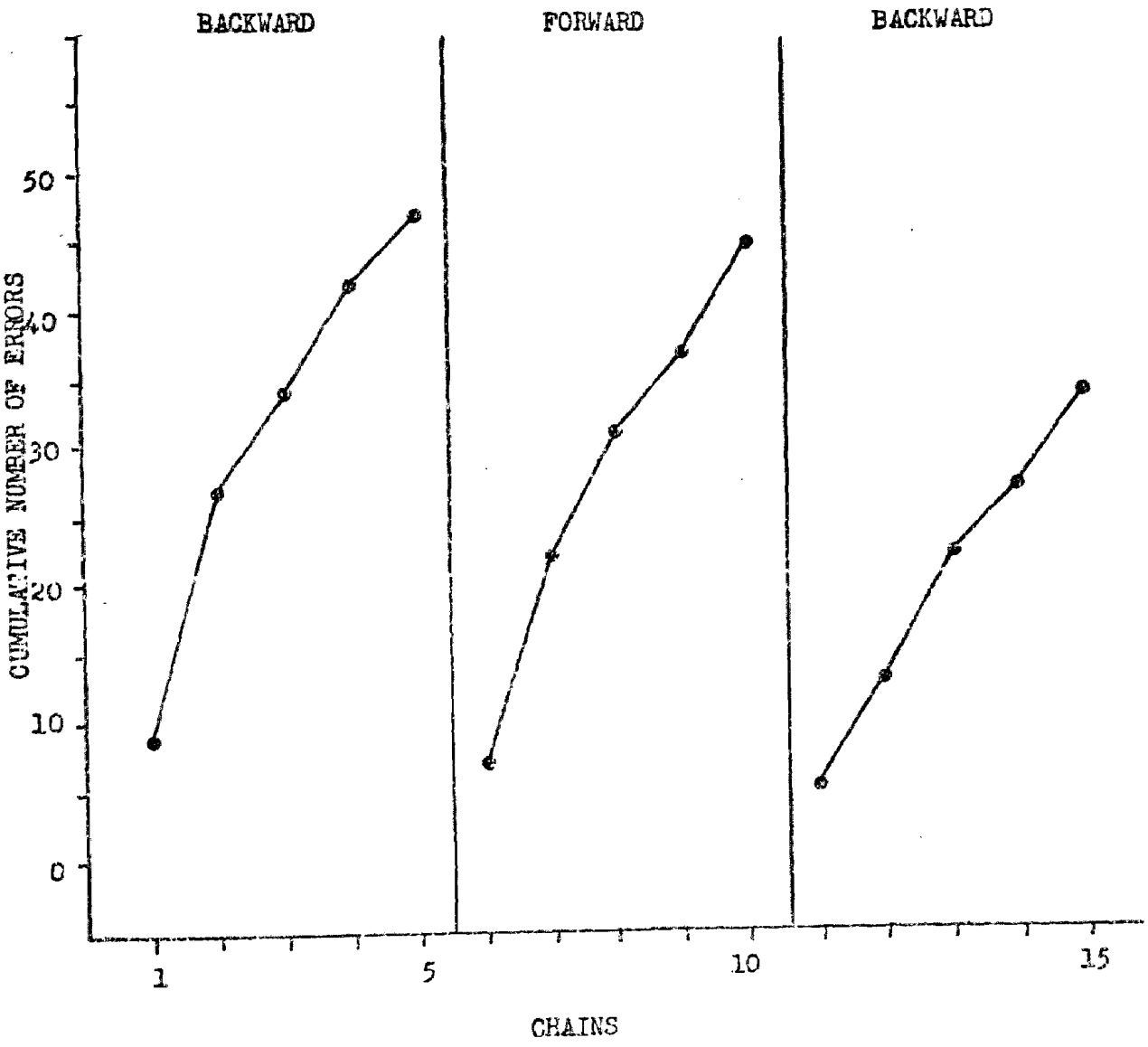

Fig. 4. Cumulative number of errors made by subject 3 during each experimental phase.

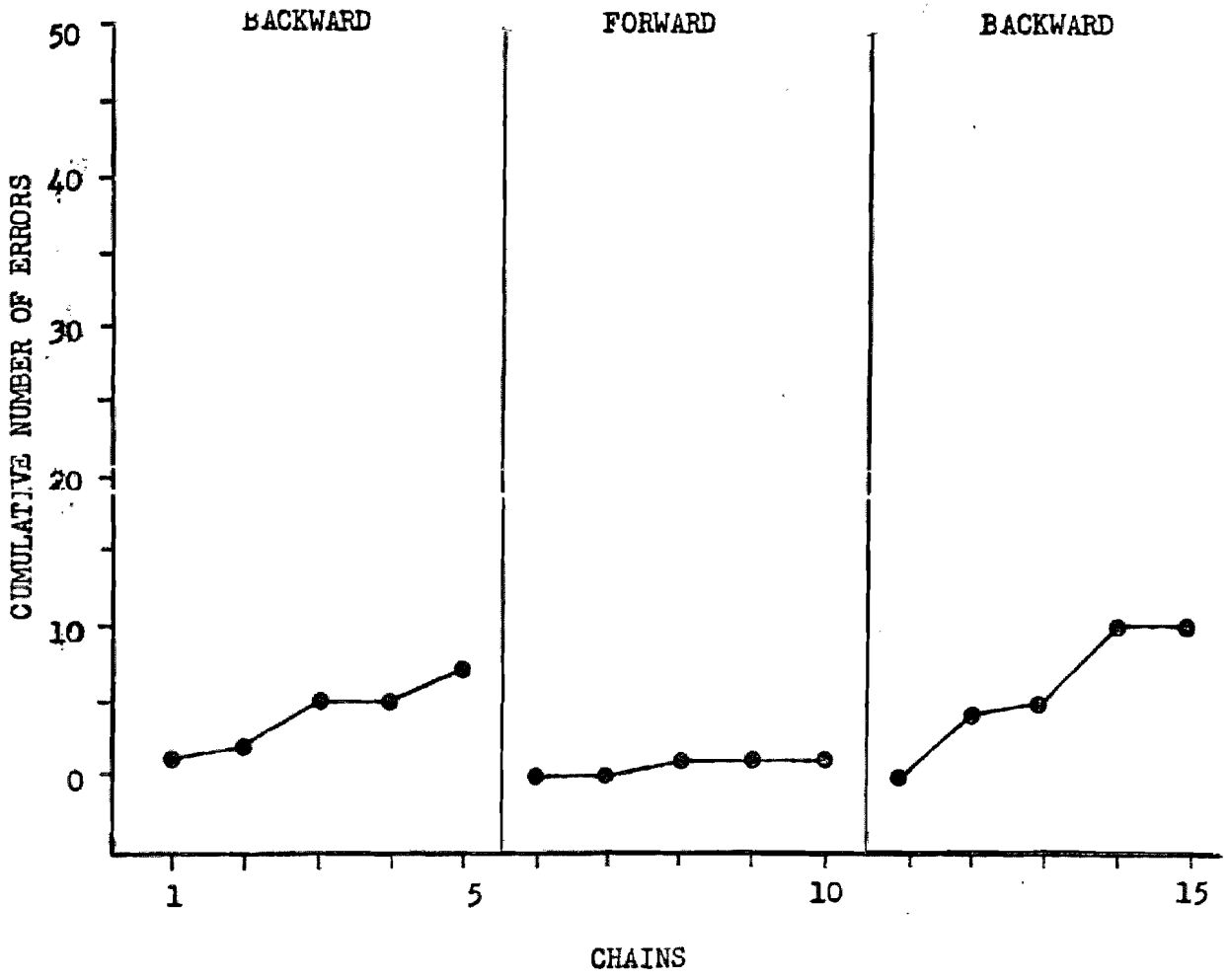

Fig. 5. Cumulative number of errors made by subject 4 during each experimental phase.

errors committed during chains three and 13.

Although subject 3 made slightly fewer errors during each successive experimental phase, Figure 4 indicates that subject 3's performance did not change greatly as a function of either the forward or backward chaining phases.

Figure 5 shows that subject 4 made fewer errors during the forward chaining phase than during the backward chaining phases. Subject 4 also made fewer total errors than any of the other subjects.

Figure 6 indicates that the number of errors made by some subjects was quite variable within the experimental phases. Figure 6 also shows that subject's error rates were not consistently high on any one chain which indicates that performance (i.e., number of errors) was not a function of the difficulty of a particular chain. For example, subject 1 made the most errors on chain four, whereas subjects 2, 3 and 4 made comparatively few errors on that chain.

In summary, the results indicated that backward chaining led to a lower error rate for subject 1 and subject 2, while forward chaining resulted in a lower error rate for subject 4. No substantial differences were observed in the performance of subject 3 under either backward or forward chaining conditions.

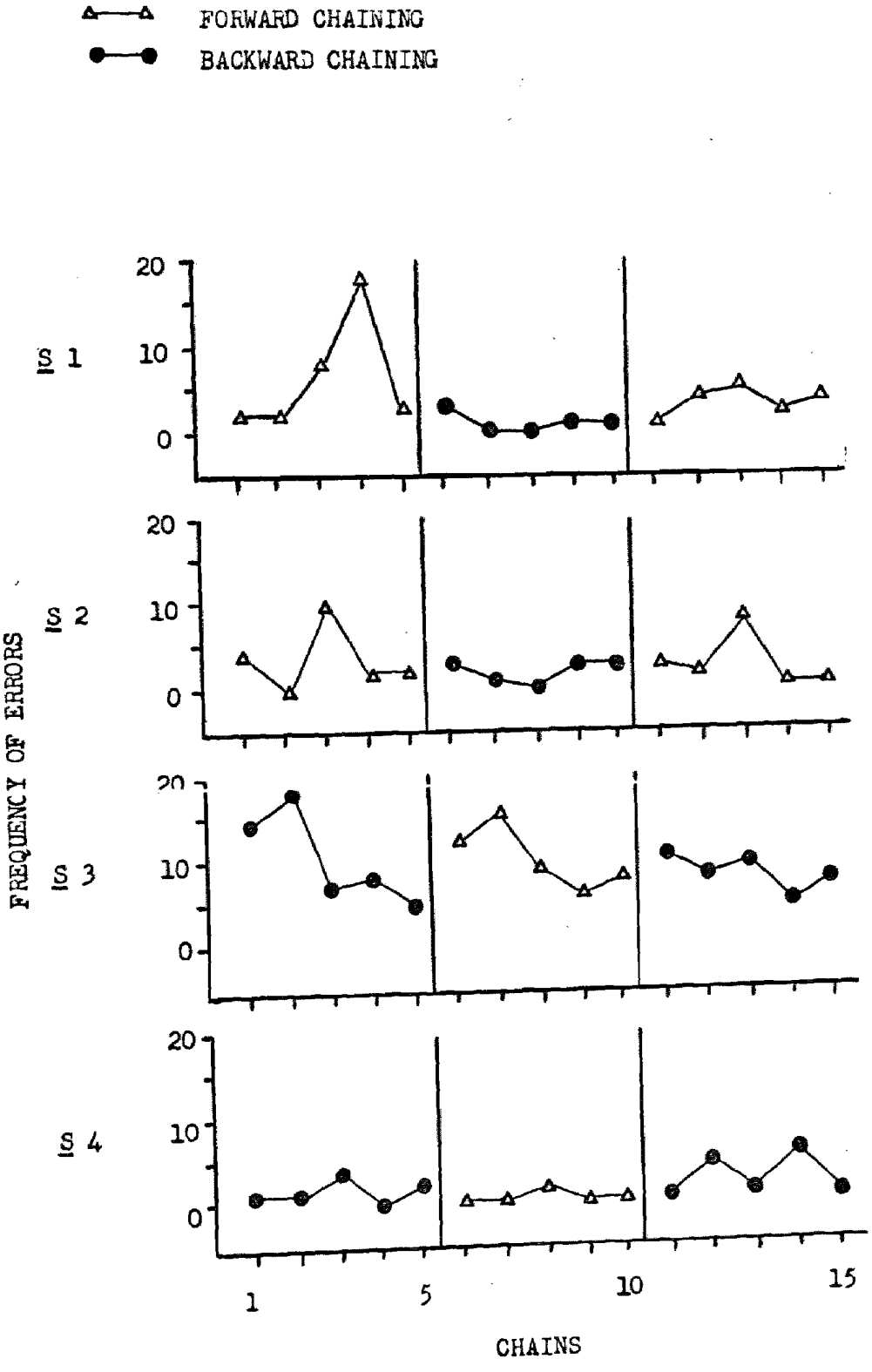

Fig. 6. Frequency of errors made by each subject during each experimental phase.

Chapter 4

DISCUSSION

The present study was undertaken to investigate the relative effectiveness of backward and forward chaining procedures in teaching retarded children to dial telephone numbers. The response measure was the number of errors made by a subject before reaching criterion on a seven response chain in either a backward or forward chaining manner.

The results of this study, with four retarded children as subjects show that backward chaining resulted in a lower error rate than forward chaining for two subjects, while forward chaining resulted in a lower error rate for one subject and there was no obvious difference in the effectiveness of the chaining procedures for another subject. The data also indicate that there was considerable variability in the number of errors made by some subjects within a chaining phase.

There are several possible explanations for these results. The fact that the results were not replicated across all subjects may have been due to the verbal behavior of the subjects while responding to the button pressing task. The subject who committed fewer errors under the forward chaining condition was observed during all phases, to verbalize each number corresponding to the button press modeled by the experimenter. Other subjects were not

observed to make verbal responses during the experiment. It is obviously possible that a subject's verbal behavior may mediate the acquisition of a chain.

The variability in the number of errors made by some subjects during a chaining phase may be due to several aspects of the training procedures. First, the remedial procedure used when a subject made an error occasionally generated emotional responses. Some subjects made comments such as "I don't want to do this any more," others tapped their fingers or banged their feet on the desk. It is possible that subjects who made one error were more likely to make other errors due to the emotional behavior generated by the remedial procedure. Second, no attempt was made to determine the strength of the tokens and backup reinforcer. Although all subjects were familiar with a token system of reinforcement, previous inconsistency in the delivery of backup reinforcers by staff at the center may have led to inconsistent responding on the experimental task.

The results of this study are inconsistent with the results of a study by Kaplan (1972), in which forward chaining was equal to or more effective than backward chaining for all 22 subjects in the study. One possible explanation for this inconsistency may be that Kaplan's subjects were all graduate students whereas the subjects in the present study were retarded children. The present results are consistent with a suggestion by Sulzer (1972) that backward chaining

may best be used when a child has difficulty in learning with a forward chaining procedure. However, it may be possible to predict the effectiveness of a forward or backward chaining procedure and to select its use prior to beginning the learning task. Variables which require further investigation include: the characteristics of the subjects, the effect of verbal behavior on the subjects performance, the nature of the task, and the training procedures used.

In summary, all four subjects did learn all 15 chains using the procedures in this study. The results show that under given conditions, backward chaining may be more effective than forward chaining for some subjects. Several possible explanations were given for the outcome of the study and variables requiring further investigation were identified. The development of the most effective educational programs requires an explicit description of the conditions under which chaining procedures are most effective. Since the acquisition of behavioral chains is essential to man's development, a knowledge of the most effective procedures in teaching these chains is most valuable.

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